Subsurface Explorer

Surface Systems Thrust

•DESCRIPTION: Approximately 0.3-1 m long, 3 cm dia, 10Kg, ~100W electrical over1-3Km fine-wire tether with samples returned to surface over 0.1 mm capillary.

•FUNCTION: Capable of penetrating 10m to 3Km (depending on vehicle length/power).

•UNDERLYING TECHNOLOGIES:

Highly efficient patent-pending percussive mechanism converts >70% of tether power to hammer energy. High voltage power system efficiently delivers power over 3Km of fine wire. Sampling system uses liquid CO2 (Mars temps) or Argon (Comet temps) to return 100μ particles to surface lander.

•Current TRL

- •TRL 2 (99)
- •TRL 6 (03)

•PRODUCT DEVELOPERS

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•CUSTOMERS

- •Mars Exploration
- •Comet Nucleus Sample Return

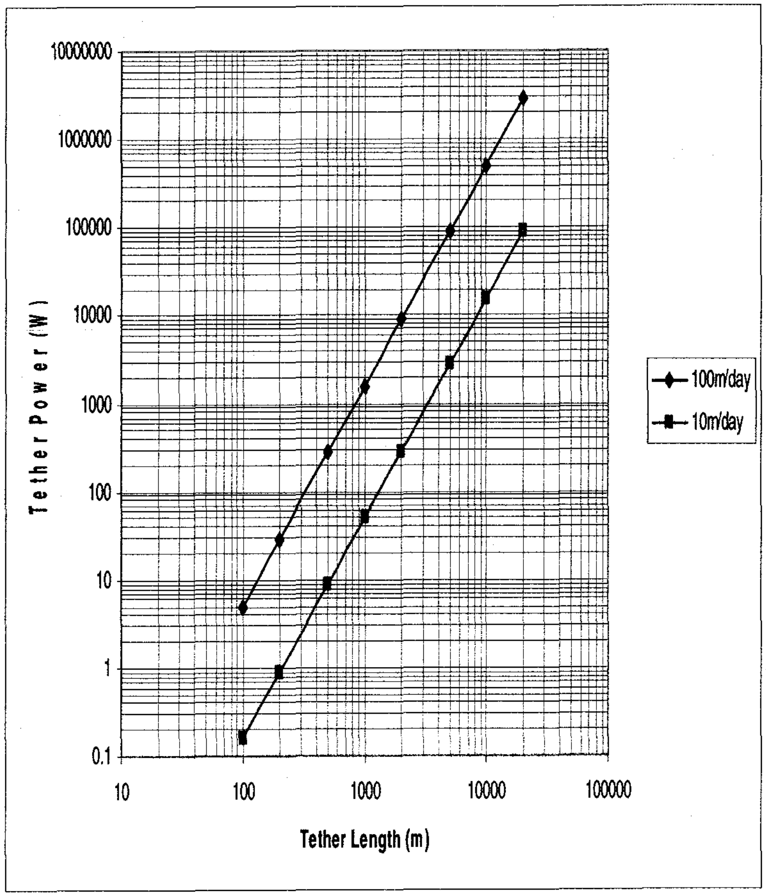
Subsurface Explorer Feasibility Analysis

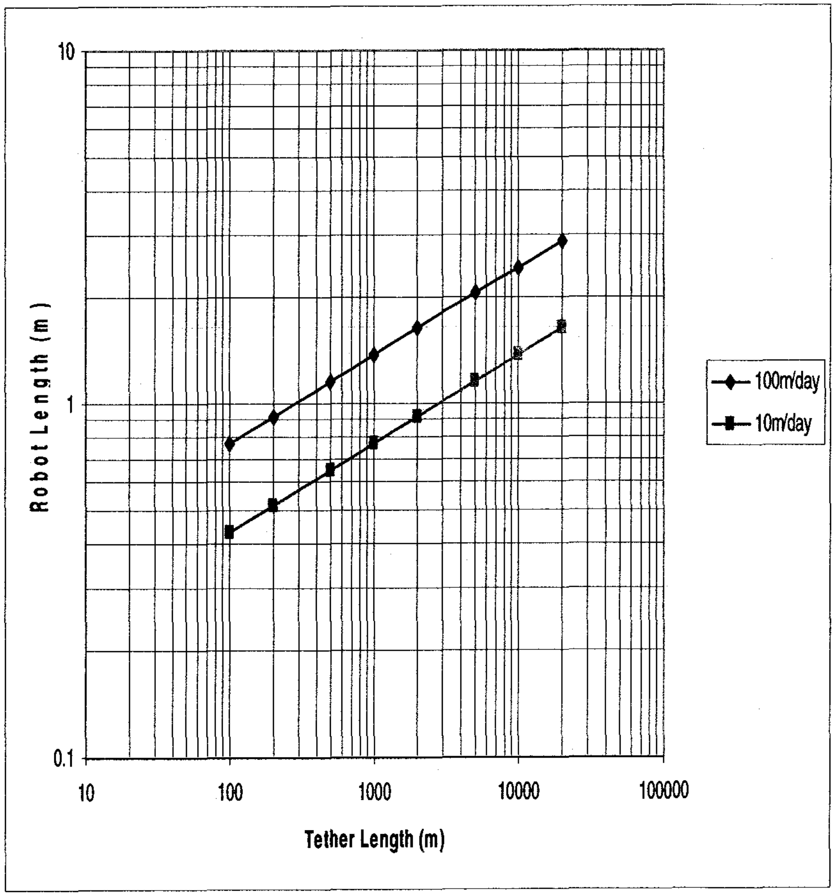
Excavation Alternatives: Specific Energy Needs

(Adapted from "Novel Drilling Techniques", by Dr. William C. Maurer, Wheaton & Co Publishers, Exeter, Gr.Br., 1968)

Excavation Method	**Rock Removal Mechanism**	**Specific Energy in med. strength rock (Mj/m^3)**	**Max Drilling Rate (m/day)**
Rotary drill	Mech. - chip formation	200-500	200-1200
Spark	Mech. - shock	200-400	500-2000
Water jet	Mech. - erosion	2000-4000	500-2000
Forced-Flame	Spalling	1500	400-800
Jet-Piercing	Spalling	1500	130-260
Plasma	Spalling	1500	100-160
Electric Arc	Spalling	1500	14-40
Laser	Spalling/Fusion	1500-5000	4-30
Electron beam	Fusion	5000	4-8
Ultrasonic	Mechanical	20,000	0.6-1

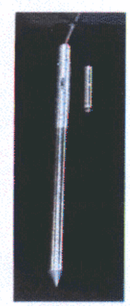
Subsurface Explorer - Energetic Analysis



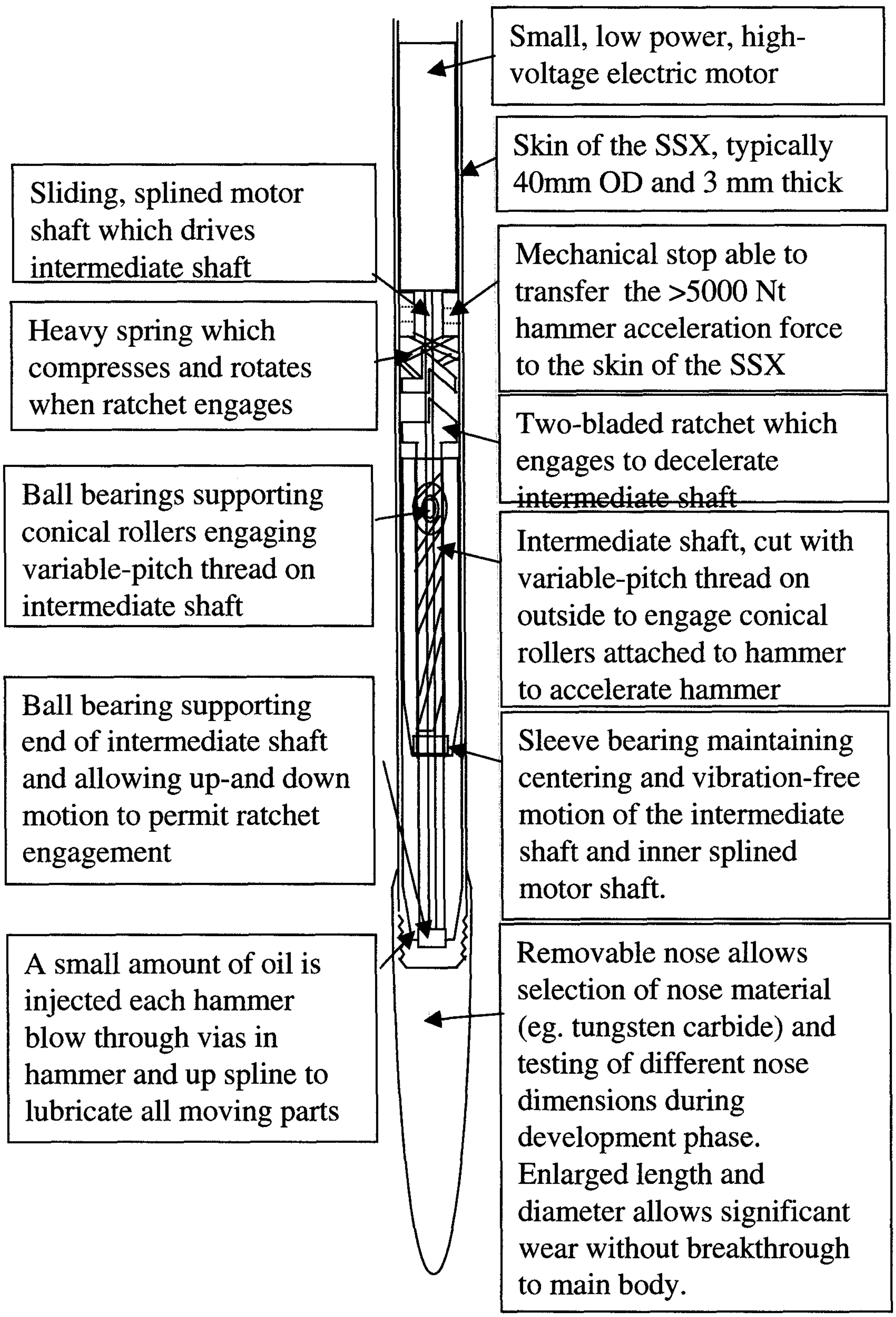


Prototype Testing

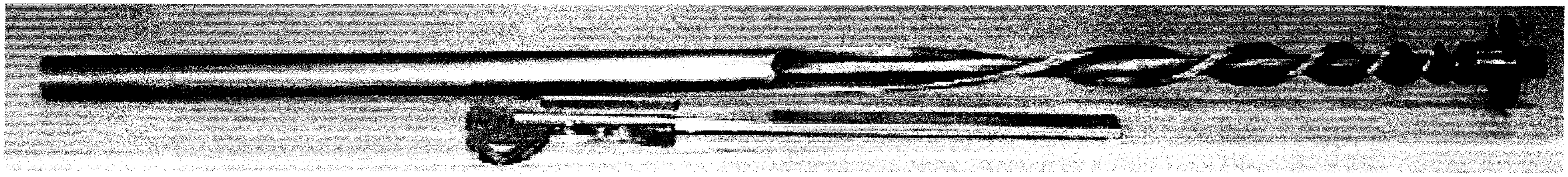
- Built 8 m vertical test facility with 0.5 m tube filled with sand (initially)
- Fabricated ~1 m percussive SSX prototype powered by compressed air
- Demonstrated prototype moving to depth of 8 meters in <3 hours
- Prototype has microscopic imaging and fiber-optic coupled Raman Spectrometer.

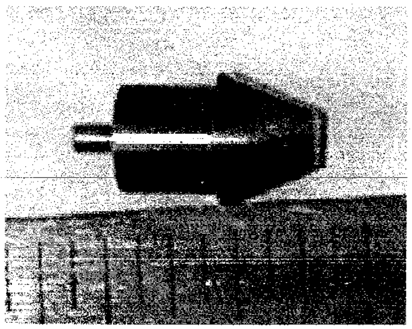


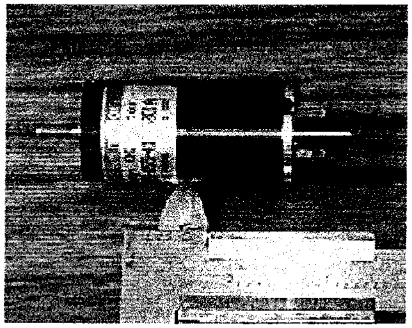
Subsurface Explorer - Spinning Hammer Percussive Mechanism



Spinning Hammer Subsurface Explorer







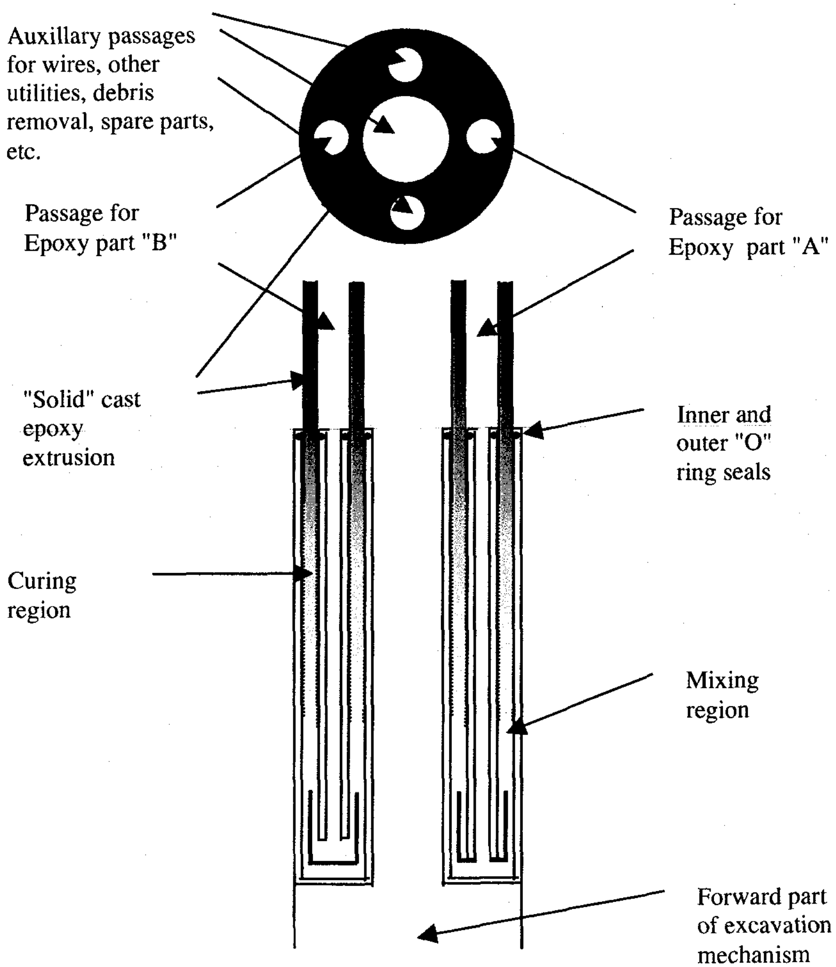
- Tungsten hammer is spun to 10-20,000 RPM on steel shaft with non-uniform threads by efficient small motor
- Hammer engages threads with two small conical steel roller bearings
- Powerful brake stops shaft in ~1/2 rotation
- Conical rollers moving along non-uniform thread put very large constant force on hammer to convert rotational energy to translational energy
- ~70% efficient at conversion of tether electric power to hammer energy vs. ~20% for alternatives
- Shock wave propagating through nose, and indexing due to rotational force, give "rotary percussive" drilling

Capillary Tubes

100 micron I.D. capillary

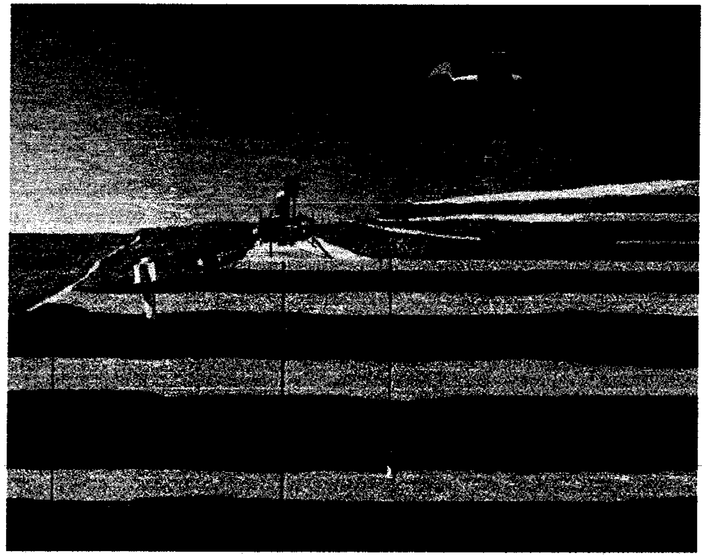
- Available in lengths of many kilometers of unbroken length for ~3$/m
- Sizes down to 100 microns I.D. and 300 microns O.D.
- Many different thermoplastic compositions (e.g. Nylon) available with wall tensile strengths ~ 40 MPa

Cast-In-Place Tether



- Uses two-part chemical mix (e.g. epoxy, H_2 & 0_2, etc.) to form hole liner from deep underground to surface
- Fluids components pass through channels cast into solid tether, are mixed, cured, and extruded at bottom
- 100 Kg of material can make hole liner with 3 mm ID and 6 mm OD 4 Km long
- Power/communication wires can be unspooled from top, eliminates need for volume of vehicle to include tether.
- Sample cores propelled pneumatically to surface

MARS CLIMATE HISTORY MISSION



Critical Technology

- **Subsurface Explorer (SSX)**
- **Microscopic Sample Handling**

Other Important Technology

- **Precision Landing Navigation & Hazard Avoidance**

- *Science Objectives*
  - Determine Composition of North Polar Layered Deposits (PLD) to a Depth of ~1 km
  - Characterize Past Volatile Cycles Related to Atmospheric Evolution
  - Determine the Age, Structure, Dust Character of the PLD
  - Search for Extra-Martian Organic Tracers that are Tracers of the Evolution of the Atmosphere
- *Mission Description*
  - Landing Site: North PLD Where Thickness Is ~ 1km
  - Subsurface: Descend / Sample to ~1000 m Depth; Return to Surface, By Capillary, <100–μm Samples for Analysis
  - Mission: Launch '07 or '09, C_3=13 km^2/s^2, ~90^d Daylight
  - Telecom: Direct Earth Comm. or MicroSats Network
  - Option: Archive Earth Return Sample - Improve Dating (AMS)
  - Cost Guess: ~$300 M, All Phases Including Launch
- *Measurement Strategy*
  - Return to Lander, Document, Separate, Concentrate, Analyze and Archive PLD Samples Every 0.2 m of Depth
  - Measure Water / CO_2 Ratio (*in situ*) and C, O and H Isotopic Ratios (MS)
  - Age-date PLD By Counting Layers and Determining Luminescence Dates
  - Determine Thermal History by Measuring Radical Abundances (EPR)
  - Measure Organic Abundances With EPR and/or MS
  - Subsurface Sounding Using GHz Radar
  - Characterization and Analysis of Dust, Ash, and Meteoritic Grains

Subsurface Explorer Feasibility Analysis:
Conclusions

- **Combination of Spinning Hammer with Capillary or Cast-in-Place Sample Return tube and Acoustic Imaging offers to make the Robotic Subsurface Explorer capable of finding extant life on Mars (if it exists) within the current planning horizon, a goal once thought unattainable.**
- **For ranges of ~100 m, the robot is small, light, and low power (<3 cm dia, <50cm long, <100 Watts); suitable as a secondary payload for shallow Mars missions.**
- **For ranges of ~1-3Km, the robot is larger (~1-2m long, ~100-200 Watts) but might be suitable as the prime mission of a lander, e.g. to search for climate history in Mars polar regions or to seek liquid water aquifers on Mars.**